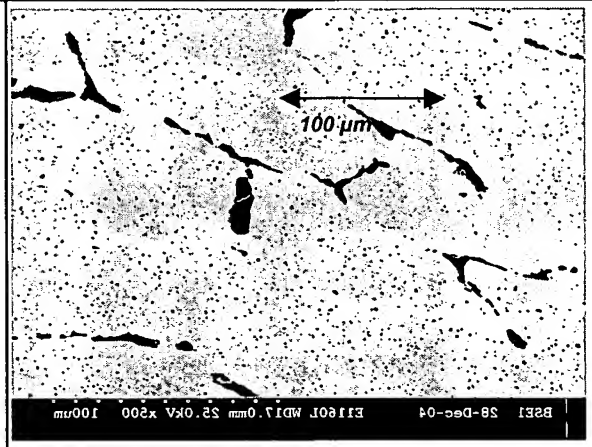
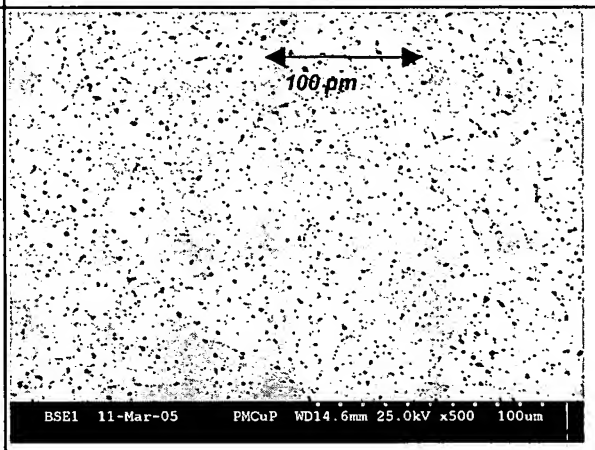
US Patent Application 10/644,220
Copper-Nickel-Silicon Two Phase Quench Substrate

Claim 1: A copper-nickel-silicon quench substrate of a thermally conducting alloy for rapid solidification of molten alloy into strip, having a two-phase microstructure with cells of copper rich regions surrounded intimately by a ***discontinuous network*** of nickel silicide and chromium silicide phases,

wherein said thermally conducting alloy is a copper-nickel-silicon alloy consisting essentially of about 6-8 wt. % nickel, about 1-2 wt. % silicon, about 0.3-0.8 wt. % chromium, the balance being copper and incidental impurities.

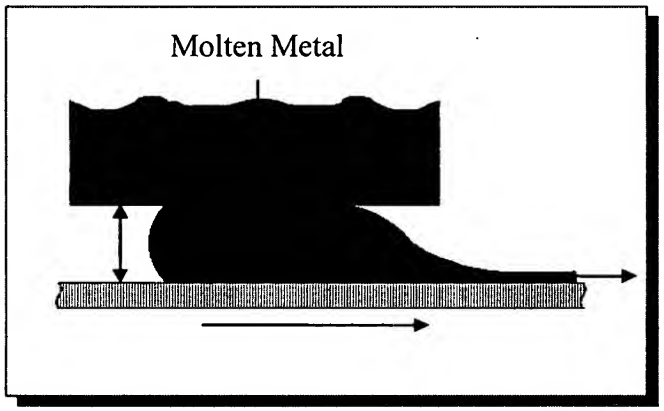
Continuous Network vs Discontinuous Network

	Microstructure
Continuous Network Recrystallized or Dendrite Cu Grains ~ 100 µm diameter Silicides at Boundaries >100 µm² Silicides Within Cu grains <5 µm² Cells Between Silicides ~ 1000 µm	
Discontinuous Network Cu Grains = ~ 50 µm diameter Silicides at Boundaries <5 µm² Silicides within Cu grains <2 µm²	

Key:
Black = CrSi
Dark Grey = NiSi
Light Grey = Cu

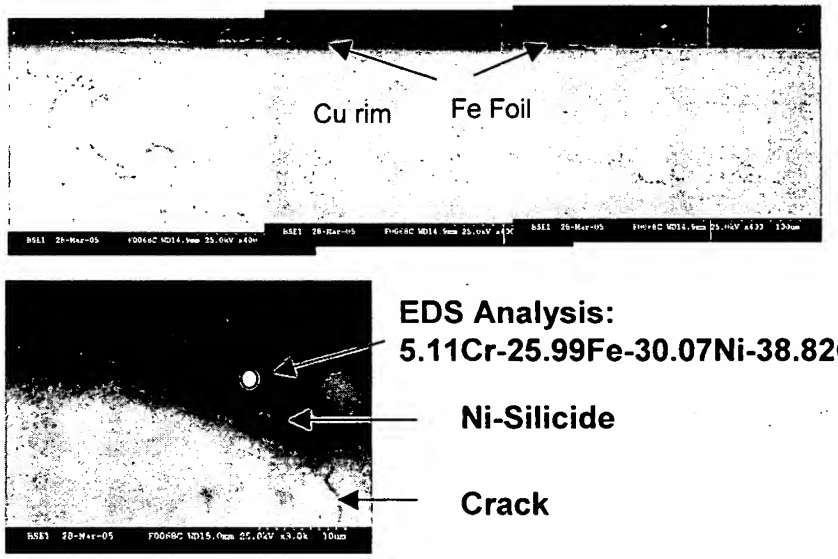
Forces Acting on Rim

Thermal Pulse from casting molten metal onto the rotating rim



- Thermal Pulse Reduces Tensile Hoop Stress
- Average Rim Temperature ~ 300ºC

Peeling from welding/stripping



- Molten Metal Penetrates Rim Surface (at large Silicides?)
- Cu, Cr and Ni Dissolution in Fe
- Cracks Extend From Weldment

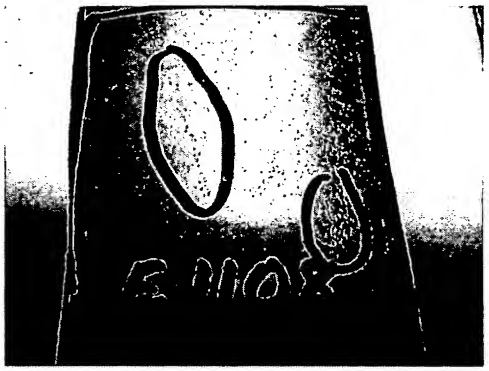
Forces Acting on the Rim are not Traditional Mechanical Stresses

Rim Failure Modes

Definitions:

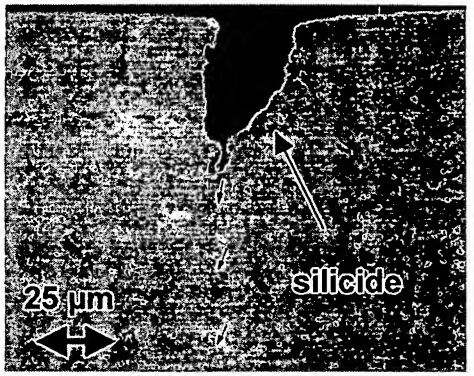
- **Pit** — Rim defect caused by intergranular failure at the rim surface
- **Pip** — Ribbon defect caused by casting over a pit
- **Pit Bands** — Localized cluster of pits on the rim surface (typical in Cu-Be rims)
- **Scars** — Localized cluster of pits on the rim surface (typical in Cu-Ni-Si-Cr rims)

Macro of Rim Surface Showing Scars



Note: Scarring is localized.
Significant "good" area.

Micro Cross Section of Rim Showing Pit and Silicides

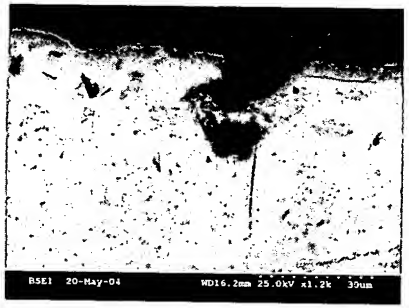


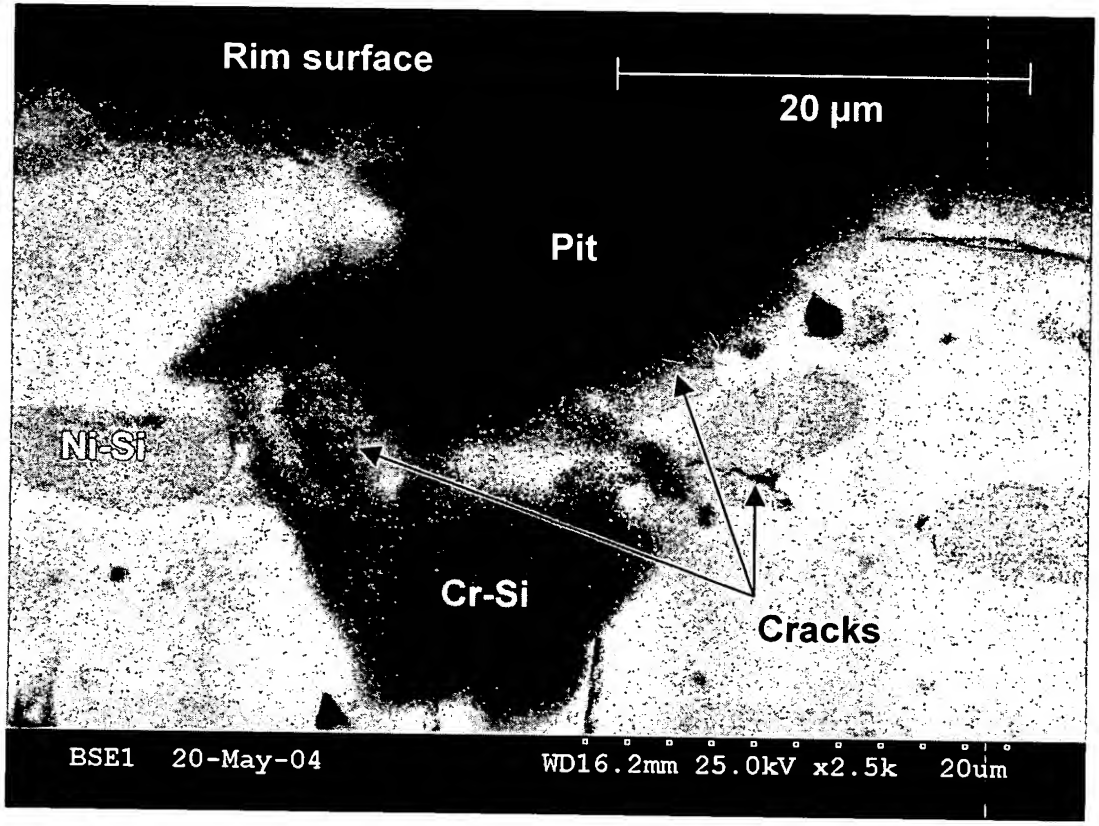
Note: Individual pit is small.
Silicide is large (>5µm thick)

Rim Failure Related to Non-Homogeneous Microstructure

Rim Surface Failure Analysis

SEM – Transverse Section



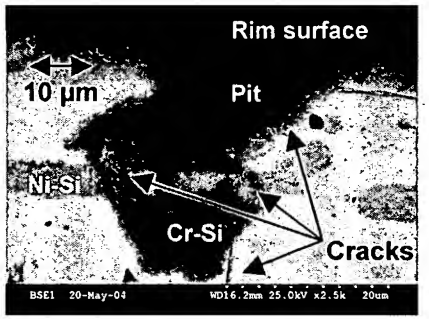


Sub-surface Crack Networks Can Create Pits…
Pits Can Expand Thru Continued Cracking

Continuous Network vs Discontinuous Network

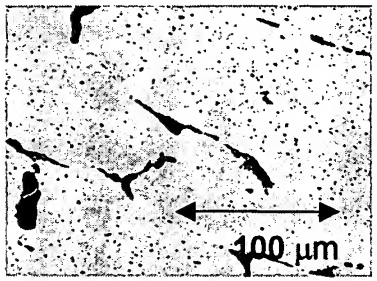
General Rim Failure Mechanism

Pit Formation via Crack Nucleation and Growth through Large Primary Silicides

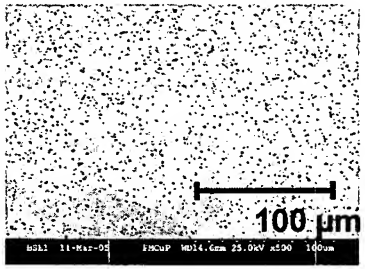


Discontinuous Network Rims Have Reduced Silicide Size And Grain Size

Continuous Network Rim
Grain Size~ 100 µm
Silicide Size up to 500 µm²



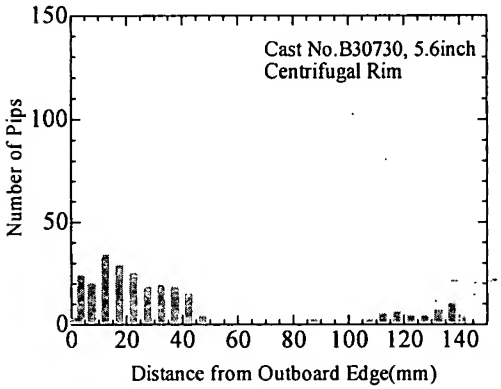
Discontinuous Network Rim
Grain Size ~ 50 µm
Silicide Size ~ 5 µm²



Rim Surface Degrades via Cracking Through Large Silicide Particles
No Large Silicide Particles in Discontinuous Network

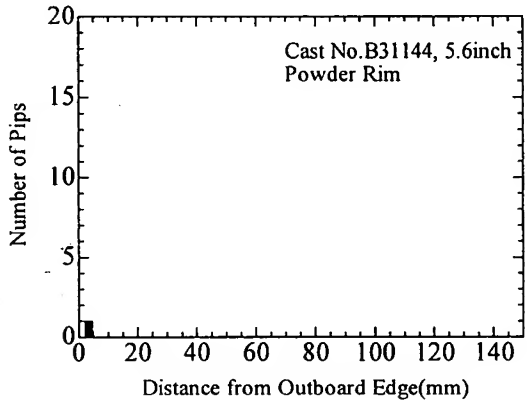
Effect on Cast Strip Quality

Continuous Network Rim



More than 50 defects

Discontinuous Network Rim



Less than 5 defects

Discontinuous Network Rims Exhibit Reduced Defect Formation, Improved Quality